

## ***Claims***

I claim:

1. Apparatus for transmitting and receiving signals that is in conformity with a communications standard or among multi-standard and comprises a carrier signal modulated by a wanted signal, said communications standard defining a plurality of communications channels having central frequencies that are separated from one another by a fixed frequency referred to as a channel spacing, the modulated carrier signal occupying one of said plurality of communications channels, the apparatus including the first high frequency(HF) PLL 103 to generate  $f_1$  and  $f_2$  at an actual local oscillator frequencies which differs from said central frequency of the channel occupied by said wanted signal by a frequency difference  $f_3$  whose frequency is generated by a programmable mixed-signal waveform generator 104 followed with Digital to Analog Converters (DAC) and a filters. The mixing operation can be up conversion or down conversion.

For up conversion  $f_{up}=f_a+f_b$  it is generated by  $\cos(2\pi f_{up}t) = \cos(2\pi f_a t) * \cos(2\pi f_b t) - \sin(2\pi f_a t) * \sin(2\pi f_b t)$ . and  $\sin(2\pi f_{up}t) = \sin(2\pi f_a t) * \cos(2\pi f_b t) + \cos(2\pi f_a t) * \sin(2\pi f_b t)$ .

For down conversion  $f_{down}=f_a-f_b$ , it is generated by  $\cos(2\pi f_{down}t) = \cos(2\pi f_a t) * \cos(2\pi f_b t) + \sin(2\pi f_a t) * \sin(2\pi f_b t)$  and  $\sin(2\pi f_{down}t) = \sin(2\pi f_a t) * \cos(2\pi f_b t) - \cos(2\pi f_a t) * \sin(2\pi f_b t)$ .

The transmitter 107 mixes the transmitted data signal and the final carrier frequency signal produced by mixing  $f_1, f_2$  and  $f_3$  frequency signals, that is  $f_c = ((f_1 + f_2) + f_3)$ , from the GRFS in FIG 1. The receiver 108 can be in direct conversion receiving or multi-stage down conversion by the frequency plan defined in this invention as shown in FIG2 and FIG3. or claim2. And multiple transceivers in different carrier channels can share the same  $f_1$  and  $f_2$  frequency generators in a communication system like multi-port WLAN switch or hub access points as also shown in FIG.1 .

2. A method according to claim 1 wherein the operation as shown in Table.1

For example, a direct conversion operation as shown in FIG. 2 , IEEE802.11a WLAN  $f_1 = 5280\text{MHz}$ ,  $f_2 = 0$  and  $f_3 = -100\text{MHz}$  to  $40\text{MHz}$  with  $20\text{MHz}$  step for lower  $5\text{GHz}$  band ( $5180\text{MHz}:20\text{MHz}:5320\text{MHz}$ ) and  $f_1 = 5940\text{MHz}$ ,  $f_2 = 0$  and  $f_3 = -195\text{MHz}$  to  $-135\text{MHz}$  with  $20\text{MHz}$  step for upper  $5\text{GHz}$  band ( $5745\text{MHz}:20\text{MHz}:5805\text{MHz}$ ).

For IEEE802.11b/g WLAN ( $2412\text{MHz}:5\text{MHz}:2472\text{MHz}$ ),  $f_1 = 2420\text{MHz}$ ,  $f_2 = 0$ ,  $f_3 = -8\text{MHz}$  to  $52\text{MHz}$  with  $5\text{MHz}$  step for IEEE802.11b and  $20\text{MHz}$  for IEEE802.11g , the  $11\text{MHz}$  baseband digital clock is also generated by  $5280\text{MHz}/480$ . For IEEE802.11b multistage low-IF receiver,  $f_1 + f_2 + f_3 = f_c - 22\text{MHz}$  as shown in FIG.10 , the  $22\text{MHz}$  difference is processing by digital mixer operation with a  $88\text{MHz}$  clock from  $5280\text{MHz}/60$ . The same low-IF approach can also applied to other wireless communication standard in the innovative frequency planning and synthesizer design. Since, the transceiver and base-band is WLAN oriented, the circuit blocks in transmitter and receiver paths such as data converters and DSP processing power in base-band are good enough to handle all the communication standard listed in table1. That is this frequency planning and architecture

of the general radio frequency synthesizer can be applied in direct conversion and low-IF and high-IF transceiver architectures. Therefore, this invention can be a general radio frequency synthesizer for current and future wireless communication standard.

For Bluetooth (2402MHz:1MHz:2480MHz),  $f_1=2420\text{MHz}$ ,  $f_2=0\text{MHz}$  and  $f_3=-18\text{MHz}$  to 60MHz with 1MHz step.

For WCDMA (1920MHz:5MHz:1980MHz),  $f_1=1980\text{MHz}$ ,  $f_2=0\text{MHz}$  and  $f_3=-60\text{MHz}$  : 5MHz:0MHz

For WCDMA (2110MHz:5MHz:2170MHz),  $f_1=2090\text{MHz}$ ,  $f_2=0\text{MHz}$  and  $f_3=20\text{MHz}$  : 5MHz: 80MHz

For multi-stage operation with a central 660MHz Band Pass Filter (BPF) as shown in FIG.3 or in Table 1, the positive and negative sign operation of  $f_2$ , can also be decoded by the base-band signal processing. The  $f_3$  frequency range is for current carious wireless communication standard, it can be extended to several hundred mega hertz and the resolution can be changed by the apparatus shown in FIG.6 to meet next generation wireless standard requirement.

3. A method and apparatus of single frequency generators according to claim1 is shown in FIG. 4. For 5280MHz, it is generated from a 20MHz crystal 401 reference signal with quadrature VCO 405 circuits to produce HF  $f_1$  signals I,Q. For minimizing phase noise for some communication standards like IEEE802.11a/g OFDM system, the frequency tuning of the PLLs' charge pump 404 are disabled during transmitting or receiving data packets. Innovative Superharmonic Quadrature Injection-Locked Frequency Dividers as shown in FIGS. 5 are invented to produce a single constant frequency analog division

operation with IQ quadrature outputs. The divider can also be implemented by a frequency divider with poly-phase filters to generate the IQ quadrature phase outputs.

4. A method and apparatus of mixed-signal frequency generator is shown in FIG6. The channel spacing is controlled by the frequency resolution control bits to choose the DAC sampling frequency and the channel spacing input bits for the input of modulo-counter/adder 601. The sampling clock can be from the output after the constant divider of  $f_1$  or  $f_2$  PLL for different communication standards. The non-linear DAC is sinusoidal waveform shaped. They share the same DAC ladder block 604 with I,Q sample and hold circuits followed by low pass analog filters 605 ,606.

5. A method and apparatus of mixer in claim 1 is Shown in FIG. 7. A two-port double balanced mixer of up-conversion or down-conversion is defined in claim 1. The mixer can also be implemented by a multiplier with image rejection filters or band-pass filters. Three input port mixer operations can be a cascade of two two input port mixer or integrated in one circuit as triple balanced mixer shown in FIG6.

6. A method and apparatus for instant/simultaneously channel switching is then be achieved according to claim1-5.

7. A method and apparatus for minimize the phase noise of oscillator is also provided in by fine tuning a single frequency oscillator instead of tuning over the extension range of VCOs in traditional frequency synthesizer with programmable counters frequency

dividers. Since the two main  $f_1$   $f_2$  are constant frequencies, the low power dividerless PLL frequency generator with aperture phase detector can also be applied in this frequency synthesizer architecture.

8. A method and apparatus for accessing multi-mode wireless communication is achieved by switching the  $f_1$ ,  $f_2$ , and  $f_3$ . For example, from IEEE802.11a to IEEE802.11b,  $f_1$  is switching from 5280MHz to  $5280\text{MHz}/3+660\text{MHz}$ . And the channel frequency is selected by changing  $f_3$ . By the same method and apparatus, this invention enables the channel carrier frequency fast switching from one standard to another one, by select the  $f_1$ ,  $f_2$ , and  $f_3$  according to table.1 . And  $f_1$  and  $f_2$  are the outputs of the constant dividers of fine tuned single frequency source. More than one communication standard can also be simultaneously achieved by adding more mixed-signal waveform generator and mixers to provide another carrier frequency without adding more the main RF PLL frequency generators to reproduce  $f_1$  and  $f_2$ .

9. A single frequency synthesizer design method and apparatus is then provided to enable a base-station or mobile station to meet multi-port wireless communication networking operation by adding more mixed-signal frequency generator  $f_3$ s without adding more  $f_1$  and  $f_2$  PLL frequency generators to save BOM cost and power consumptions. With the same method, the invention also enables the apparatus to provide carrier frequencies in multi-mode or multiple standards simultaneously in the cost effective frequency synthesis solutions. And the  $11\text{MHz} \cdot N, N=1,2,4,8,\dots$  for IEEE802.11b/g and cable modem baseband clock can be generated from the 5280MHz VCO by the constant frequency dividers.

Therefore, this invention is also suitable to be applied in a broadband gateway or router systems with wireless links.

10. Method and apparatus apply not only the standard in claim2 or table 1. but also for current others communication standard and the future next generation communication standards.

11. The mixed-signal waveform generator in claim 4 can also be a summing of multiple frequency generators to enable the broadcast function in wireless communication network. The compact version of multiple frequencies generator is a FFT processor. The  $f_3$  mixed-signal waveform generator can also be replaced by a traditional direct digital frequency synthesizer. The frequency range of  $f_3$  is not limited by table1. The range can be extended by modifying the design in FIG.6.

12. The claim of the frequency synthesizer for multimode and multi-standard wireless communication can be any combinations of the communication standards in claims 2 / Table 1 and claim 10.